CANADA
DEPARTMENT OF AGRICULTURE
ENTOMOLOGICAL BRANCH
HON. W. R. MOTHERWELL, Minister J. H. GRISDALE, Deputy Minister
ARTHUR GIBSON, Dominion Entomologist

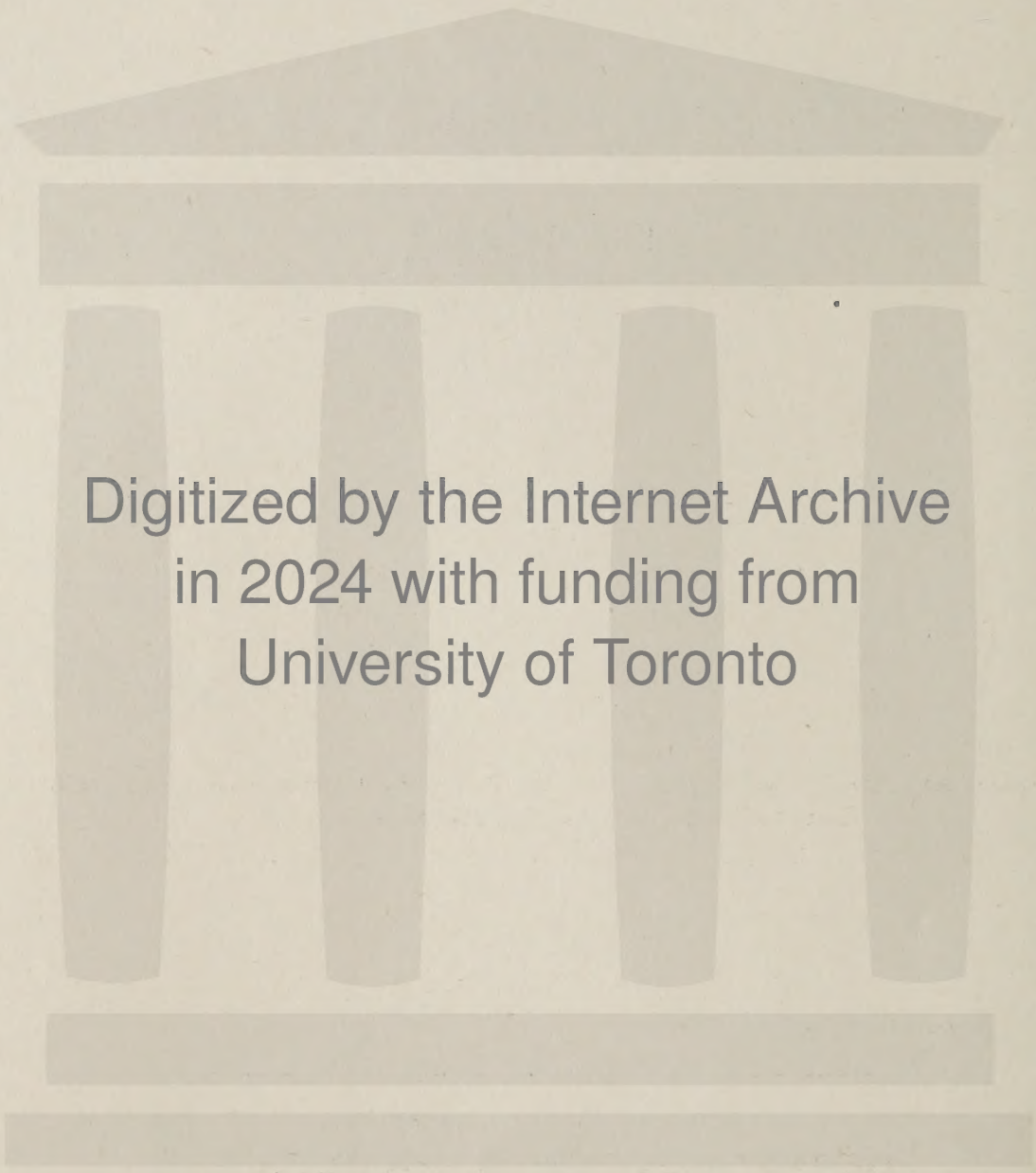
FOREST ENTOMOLOGY AND ITS DEVELOPMENT IN CANADA

BY
J. M. SWAINE, M. Sc., Ph. D.,
Associate Dominion Entomologist

(Paper presented to the Third British Empire Forestry Conference, held in Australia and New Zealand, August to October, 1928)

DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE
PAMPHLET No. 97 N.S.

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928



Forest Entomology and Its Development in Canada

By Dr. J. M. Swaine, *Associate Dominion Entomologist, Ottawa*

Forest entomology, commenced as a serious study by J. Th. Ratzeburg in Germany in the first half of the 19th century, was developed subsequently by many workers in Europe in connection with the general question of forest protection. Methods were devised for the direct control of forest insect outbreaks that could be applied under the plans for forest management, and many of these methods are still employed in a modified form in many parts of the world to-day. European workers are taking a prominent part in developing new and more efficient methods of control.

Important injuries have occurred in recent years in various European forests caused by species of *Myelophilus, Pissodes, Hylobius, Ips* and *Melolontha, Dendrolimus pini* L. *Liparis monacha* L., *Evetria buoliana Schiff., Tortrix viridana* L., and many others. These problems were discussed by Dr. Munro at the last Empire Forest Conference.

Practical forest entomology in Europe has been assisted very greatly by the enormous mass of biological data concerning insects affecting forest trees that was rapidly accumulated by many students, many of whom were not greatly concerned in the practical application of their work. Assisted very largely by this biological information several European text-books on forest entomology have been published, and these again must have stimulated forest insect investigations to a very marked degree. Even to-day the progress of forest entomology in North America is hampered by the lack of definite knowledge on the biology of many forest insect species, resulting from the relatively small number of workers who have devoted their attention to that field; and, due principally to the lack of this biological knowledge, no comprehensive text-book on forest entomology has yet appeared in either the United States or Canada.

In North America, the study of forest entomology was developed by Dr. A. D. Hopkins, until recently the Chief of the Division of Forest Entomology at Washington. Owing very largely to the successful work of Dr. Hopkins and to the influence of his publications, there has been, during the last twenty years, a very considerable development in forest insect investigations in both the United States and Canada.

In the United States there have been very extensive injuries by many species of insects affecting forest trees, shade trees, and stored wood products. The most notable losses in recent years have been caused by *Dendroctonus* beetles in western pines, southern pines, and eastern white and red spruce, *Pissodes strobi* Peck in young white pine, the locust borer, and various boring species; many defoliating species such as the spruce budworm, the jack pine sawfly, and the hemlock looper; and important injuries to stored wood products have been caused by powder-post beetles and termites.

FOREST INSECT PROBLEMS IN CANADA

Forest insect investigations in Canada are conducted chiefly by the Forest Insect Division of the Entomological Branch in the Canadian Department of Agriculture. The officers of the Forest Insect Division work in close association with the Forestry Service, Department of the Interior, and with the Forest Services of the various provinces.

The Division has its headquarters at Ottawa, Ontario, and permanent field stations are established at Fredericton, New Brunswick; Ottawa, Ontario; Indian

Head, Saskatchewan, and at Vernon and Vancouver in British Columbia. In addition to these permanent stations, many sample-plot stations and temporary study stations are established throughout the Canadian forest wherever the need arises. There are at present ten permanent investigative positions in the Division, and these have associated with them each season approximately the same number of temporary seasonal positions filled by students or specialists.

The investigation of shade tree insect problems is also conducted by this Division. Shade tree insects are studied through the cities and towns of Eastern Canada whenever outbreaks occur, and from the Ottawa laboratory. Some of the most important shade tree insect investigations have been conducted in the Prairie Provinces from the Indian Head laboratory in connection with the plantations of poplar, maple, and other deciduous trees which have been developed there very extensively.

The more important timber trees of the Canadian forests are conifers; various species of *Pinus, Picea, Abies, Thuja, Larix,* and *Tsuga* and, in addition to these, *Pseudotsuga* and *Chamaecyparis* in British Columbia. Our more important forest insect investigations have been concerned with outbreaks of insects affecting these coniferous species, such, for example, as the spruce budworm (*Cacoecia fumiferana* Clem.), the larch sawfly (*Lygaeonematus erichsoni* Hart.), the hemlock looper (*Ellopia fiscellaria* Gn.), species of *Monochamus, Pissodes strobi* Peck and *Pissodes dubius* Rand., *Dendroctonus piceaperda* Hopk., *Dendroctonus brevicomis* Lec., *Dendroctonus monticolae* Hopk., and other species of *Dendroctonus,* and the western cedar borer (*Trachykele blondeli* Mars.).

The control of insect outbreaks spread over even hundreds of square miles of forest land presents great difficulties, with reference both to the possibility of killing the insects and the expense of the operation. An account of a few important problems will best illustrate the methods of investigation and control which are being employed.

The Spruce Budworm

During the last twenty years, very extensive and exceedingly destructive outbreaks of a defoliating caterpillar, known as the spruce budworm (*Cacoecia fumiferana* Clem.), have occurred throughout the forests of southeastern Canada, in which it has been estimated that as much as two hundred million cords of pulpwood have been destroyed.

The moths of this species appear in midsummer and deposit their eggs in small masses on the needles. The young larvae hibernate without feeding, each in a silken case, on the twigs, and attack the opening buds and young shoots in the following spring. The young foliage is preferred by the larvae; but the old needles are sometimes mined by the young larvae in the early spring before the buds are open, and the old foliage is eaten also to a varying degree by the large larvae after the new foliage has been destroyed.

While all species of *Picea* and *Abies* are affected in these eastern outbreaks, the chief destruction has occurred in mature stands of balsam fir and in the red spruce of the Maritime Provinces. The spruce budworm occurs also in the mountain balsam and Douglas fir forests of British Columbia; but the outbreaks in that province have usually lasted only two years and then disappeared without causing very serious injury. Serious outbreaks have occurred recently, however, in the Rocky Mountain region of the United States.

The Great Eastern Outbreak

The greatest of these spruce budworm outbreaks commenced about 1909 in northern Quebec and spread southward, crossing the St. Lawrence river in 1914. At the same time a similar outbreak was spreading in Maine and New Brunswick. The entire coniferous forest of Eastern Canada, east of the Ontario line and south

of the Height of Land, was eventually affected, excepting only the Gaspé peninsula, and a vast quantity of balsam fir and spruce pulpwood was killed and has since very largely decayed. By the year 1923 the active feeding had ceased nearly everywhere except in Cape Breton island and in central Ontario, where smaller outbreaks are still present. In Quebec and New Brunswick the feeding lasted only about three years in any one locality and then gradually disappeared. Much of the balsam fir died very rapidly following heavy defoliation, but a large part of the stand struggled on for five years or longer and gradually succumbed.

The Entomological Branch conducted an exhaustive study of this outbreak, paying particular attention to the exact relation of the insect attack to the health of the trees, the natural conditions which bring about these great outbreaks, and the factors which cause their decline, with the hope, of course, of providing some effective methods for prevention and control.

The trees were injured or killed outright by the defoliation, but the effect of apparently the same degree of feeding varied greatly in different parts of the same stand. The habits of the insect provide a partial explanation for this variation.

The caterpillars hibernate on the twigs as first-stage larvae, and emerge and commence feeding in the spring as soon as the balsam fir buds open. In Quebec and most of the Maritimes, the balsam fir and white spruce buds open from one to three weeks earlier than those of the red and black spruce. The caterpillars develop rapidly on the growing balsam fir shoots, most of which are killed in a heavy infestation, and a very high percentage of the caterpillars normally reach maturity. The white spruce shoots grow with such rapidity that in a normal attack they complete their growth in spite of the feeding of the caterpillars. The red spruce buds are usually very short when the caterpillars appear, but provide sufficient food to suffice for their development. The black spruce buds, on the other hand, are rarely open at all when the caterpillars appear, and, though the caterpillars bore into the buds and kill them one by one, they develop very slowly and probably a smaller percentage in this case mature and reach the adult stage. As a result of these relations it is found that the balsam and red spruce are killed very extensively, in heavy outbreaks to an extent of more than eighty per cent, while white spruce is less commonly injured seriously and the black spruce of Quebec and Ontario is rarely very seriously injured at all.

However, it is found that in the Cape Breton island outbreak the conditions are peculiar in several respects. The balsam fir buds are less commonly killed, but frequently develop to normal length and form the terminal buds as usual. The caterpillars feed on the growing needles and frequently strip the new twigs completely, leaving the bare twigs with next season's buds normally developed at the end. This may continue for several years without killing the trees, and apparently with a considerable percentage of the caterpillars maturing each season. It appears that the outbreak may have lasted for nearly 15 years in some parts of Cape Breton island, and still a considerable percentage of the stand is green.

The explanation of this condition appears to lie in a relatively earlier opening of the buds, the caterpillars being retarded possibly by cold air temperature enduring in spring long after the roots of the trees have been released from the frost. A study of air and soil temperatures in different parts of the eastern forest is being undertaken.

It is interesting, also, that whereas the balsam fir appeared to be the favourite food-plant in Quebec and New Brunswick, in Cape Breton island areas have been noticed where the spruce was being killed extensively and the balsam fir in the same stand was but little injured. A study of these conditions is still in progress.

In the general outbreak the heaviest injury occurred in mature stands of nearly pure balsam fir, young and fast-growing stands being less seriously injured. As a rule, the higher the percentage of balsam fir in a mature stand the greater was the mortality. Based on these facts, recommendation has been made that balsam fir and spruce pulpwood should be managed on a short rotation, the over-mature stands with a high percentage of balsam fir being utilized as rapidly as possible, and thereafter the older balsam fir being systematically cut first, so as to produce, as rapidly as possible, a young and thrifty growth over the entire balsam-spruce area. In such a forest a budworm outbreak would probably never develop to very serious proportions.

It was observed very generally that the moths preferred to lay their eggs in the upper, exposed parts of the crown, and did not commonly penetrate much below the crown-cover. Coniferous stands growing under a hardwood canopy were usually immune from serious attack. Nevertheless, in the present outbreak in Central Ontario, balsam fir has been killed extensively under a heavy hardwood cover. Curious differences have been noticed in the degree of injury sustained in different areas in the same forest, apparently to be explained in some part by the varying composition of the stand. The varying intensity of the light penetrating the foliage of different forest mixtures, and the relative humidity at different levels in different mixtures may explain some of these differences, and offers a promising field for study.

It has already been mentioned that the mortality continued for several years after the feeding of the caterpillars had ceased. It was found that many of the outer roots had died on trees previously defoliated by the budworm. Dr. Faull's study of the white pine blight suggests an explanation for this.

Fungi

The budworm-weakened stands were heavily infested with wood-destroying fungi and with several species of secondary insects. The fungi affecting the balsam fir and spruce in these areas have been studied by Dr. Faull and Mr. McCallum. The destruction by wood-rots forms an important feature of the budworm outbreaks. The rapid decay of the dead trees shortens the period of salvage and enormously increases the total loss. It is interesting that in Newfoundland there is very little of this injury by wood-rots. Balsam rots and Monochamus beetles are almost unknown on a large part of that island, while both are abundant in the neighbouring island of Cape Breton. It would be interesting to have an explanation for this difference.

Secondary Species

It was at one time thought that several other insect species, which apparently followed a budworm outbreak, might be of some importance in killing the weakened trees. The balsam sawyer (*Monochamus marmorator* Ky.), the balsam bark-beetle. (*Pityokeines sparsus* Lec.), the balsam weevil (*Pissodes dubius* Rand.), and the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.), were the most important.

It now appears that the balsam bark-beetle attacks only dying trees, and, although the balsam sawyer does attack living trees, both by ovipositing in the bark of the trunk, and by gnawing the bark of the twigs for food, it is at most of only local importance.

The *eastern spruce beetle,* while frequently present in the budworm-injured forest has not been found by us at all abundant in budworm-weakened spruce. The relatively dry condition of the bark in these trees is possibly not attractive to them. A study of sap changes in dying trees is indicated.

The balsam weevil is commonly found feeding and egg-laying in healthy, weakened, and dying trees, but its broods are apparently able to develop only in trees in a weakened condition. In the study of this problem the Entomological Branch had the co-operation of a plant physiologist, and through his aid some interesting points were discovered. The beetles apparently spend the entire first season in cutting food punctures in the bark of the trees, without laying eggs. The eggs are practically all deposited during the second year of the beetle's lifetime in punctures similar to the food punctures cut in the bark of the trunk. It was found that each food puncture was surrounded by an area of resin cells eventually producing a flat resin pocket just beneath the bark. When the feeding is very abundant, even a healthy tree may conceivably have the sap flow reduced in this way to such a degree that eventually the brood attack may completely reduce its resistance and kill the tree.

It has been found difficult to decide whether a tree is actually dying or whether it still has a chance for recovery. If certain boring insects are attacking only those trees which would die in any event, control measures would be unnecessary. An exhaustive study of cell-sap changes is needed also in connection with this investigation. Other interesting conditions were dealt with in this joint study and it was once more emphasized that the plant physiologist and the biochemist must play a very important part in the solution of many forest insect problems.

THE ORIGIN AND DECLINE OF OUTBREAKS

The causes which bring about the development of these great outbreaks are still imperfectly understood. The budworm is a native insect and is always present in the coniferous forests. Previous outbreaks have occurred, some of these over large areas, at intervals of a generation or more. Something has been learned of a few of these older outbreaks, through local records and the examination of the annual rings in very old trees, which have survived the earlier attacks. The last outbreak apparently developed in extensive overmature balsam fir stands in Northern Quebec and New Brunswick and spread from these to the surrounding areas. There was no study being made of this problem in the years just previous to 1909, and knowledge of the early progress of the infestation is very meagre. We have learned most from a study of the narrow ring-growth made during the years of the outbreak. There is much evidence that the outbreak developed at nearly the same time throughout much of the whole eastern forest, so that evidently similar conditions were resulting in many places in the rapid increase of the budworm population. Favourable climatic conditions occurring for several years in succession, coming at the time when there was an enormous stand of overmature balsam waiting to be killed is the simplest explanation; but there is no definite evidence that this is really the explanation at all. An exhaustive study of climatic changes in our forests and their relation to insect activities is needed.

The decline of the outbreak was brought about in many locations by the exhaustion of the available food-supply, and from these defoliated areas there resulted at times great flights of moths to the surrounding areas. Cold, wet weather in the period preceding pupation was probably effective in controlling the outbreak in the Restigouche valley in New Brunswick, and adverse weather conditions may have had considerable effect in other places. Parasites have not proved effective, as a rule, in controlling these outbreaks in the East; although they do seem to be unusually abundant now in the Cape Breton island outbreak and there is some evidence that they are an important factor in the infestations in British Columbia. In the great eastern budworm outbreak there appeared to be, on the whole, no effective natural control until the food-supply was exhausted. There is now under consideration the importation of parasites of

European species allied to the budworm in the hope that it may be possible to add another control factor to those already operating in our woods. It is important now to study the biology of the insect while its numbers are few and to follow in minute detail its progress towards the next general increase.

METHODS OF DIRECT CONTROL

The principal of management that has been described for the eventual prevention of budworm outbreaks would take years to perfect. In the meantime it is necessary to provide, if at all possible, some effective means of direct control, so that outbreaks can be dealt with in their initial stages as soon as they appear.

The distribution of poison dusts over the infested forest by means of air machines has seemed to offer more hope than any other as a method of direct control. This method has been employed with success for the control of other defoliating forest caterpillars in both the United States and Europe; but there are two factors which render this method difficult of application to budworm outbreaks. The budworm feeds, in many cases, by boring into the buds before the latter have fully opened; and the buds of a mixed coniferous stand open irregularly. It is desirable to apply the dust while the caterpillars are small, since they are then most easily killed; but at that time they are most likely to be boring in the partly opened buds and therefore in great measure protected from the dust. The partly grown caterpillars frequently construct a loose tube of silk which in some measure protects them from the dust. When the buds of balsam fir are open sufficiently to permit the dust to penetrate to the axis, those of red spruce, which open from one to three weeks later, are usually closed or only partly open; so that it will often be difficult to dust a mixed stand effectively. There is the further difficulty that the dust must be applied within a short period of time and in a season when weather conditions are likely to be unfavourable; and, in addition, the cost of the operation might be prohibitive.

Nevertheless, the possibility of success appeared to be sufficiently great to warrant a series of thorough experiments. If a method of dusting could be perfected by which the budworm could be destroyed effectively, even though at considerable cost, it might prove of incalculable value in protecting valuable stands of timber or even in checking the development of incipient outbreaks.

It was accordingly arranged, through co-operation between the Entomological Branch of the Canadian Department of Agriculture and the Canadian Air Service, and consultation with the Dominion Forest Service, to conduct an air-dusting experiment in the spring of 1927 on a spruce-budworm outbreak occurring at that time in Cape Breton island. The Canadian Air Service provided a special dusting aircraft, with a pilot, mechanics, and the necessary equipment; the Department of Agriculture provided the dust and planned and supervised the experiment, with the co-operation of the Nova Scotia Forest Service, which also provided a large amount of dust for a continuation of the experiment which they supervised on a budworm outbreak in Antigonish County on the mainland of Nova Scotia. The whole method of procedure was new under the forest conditions which obtained in that outbreak; the best plots available were composed of mixed stands of balsam fir, spruce, and hardwoods on which the infestation was only moderately heavy; the balsam fir and spruce buds opened very irregularly, and consequently the balsam fir buds were ready for dusting at a time when the spruce buds were still largely unopened; unfavourable weather conditions developed at the period when the dusting required to be done; great difficulty was experienced in marking the plots so that their boundaries could be clearly discerned by the pilot when flying low over the tree tops; and, in addition, some trouble was experienced with uneven liberation of dust from the hopper.

These difficulties were eventually surmounted, however, and the dust was applied in varying doses to a series of selected plots with a fair degree of exactness. The work had to be discontinued before all the largest plots were treated, owing to the lateness of the season.

It proved difficult to estimate the effect of the dusting correctly through counting the caterpillars on special branches before and after the operation, since the caterpillars drop to the lower foliage, to a greater or less degree, during winds and drop very readily when the foliage is disturbed by climbing the trees.

The dead caterpillars in most cases either remain attached to the twigs on which they were feeding or are caught on the lower foliage, so that a relatively small number were obtained on the canvas sheets spread beneath the station trees.

Rainy weather, which interfered with the dust application, continued throughout the month of July and part of August, accompanied frequently by high winds. The rainfall on the sample plots during the month of July was 4·28 inches, and there were only nine days in the month when rain did not fall.

Within a few days following the dusting the caterpillars on the plots were found to be dying in considerable numbers, and this mortality continued for the following two weeks. On the check plots, however, the same condition was apparent, though to less degree. It soon became evident that a few of the caterpillars were killed by fungi and that a very large number of them were parasitized. A subsequent study showed that on the whole area infested by the budworm the parasitism reached as high as 75 per cent. It was, therefore, exceedingly difficult to determine the precise effect on the caterpillars to be ascribed to the poison.

After the feeding of the caterpillars had ceased for the season, a careful study of the defoliation was made on the sample plots and on nearby check plots, using the type maps already prepared. Since the red and black spruce buds were imperfectly opened when the plots were dusted, very few caterpillars were killed on that foliage and the defoliation on red and black spruce varied little between the plots and the checks.

On the balsam fir, however, the defoliation on the plots was noticeably lighter than on the checks. It should be stated that the caterpillars were approximately one-third grown when the dusting was done and had, therefore, already eaten sufficiently to make their work noticeable. The defoliation over the whole infested area was light, very much less than in the previous year, and small differences in defoliation were not easy to detect.

On the plots dusted with 30 pounds per acre, the balsam defoliation was noticeably lighter than on the check plots and on those dusted with 15 pounds per acre. Smaller differences were noticed between the balsam defoliation on the check plots and the 15-pound plots, and between that on the latter and on the 20-pound plots.

When allowance is made for the defoliation that had already occurred before the plots were dusted it seems probable that 30 pounds per acre gave a fairly satisfactory control on balsam foliage. Future experiments should chiefly employ 30 pounds and 20 pounds per acre; and while 15 pounds and 10 pounds per acre should be tried again, they appeared in this experiment to be too weak.

Guided by the experience gained in the Cape Breton experiment, the dusting tests were continued in 1928 in a spruce-budworm outbreak near Westree in the province of Ontario, the Entomological Branch and the Canadian Air Service being assisted on this occasion by the Ontario Forestry Branch.

Twelve plots, each 500 feet long, and 5 single-swath lines, each 1,000 feet long, were laid out and marked by flags for the guidance of the pilot. The plots were to be treated with three brands of calcium arsenate in doses of 10, 20, and 30 pounds per acre, and heavier doses were to be applied to the single-swath lines.

Very unfavourable weather conditions and a serious accident to the only plane available interfered with the application of the dust, but it is hoped that valuable data will be obtained from this year's experiment.

The Eastern Spruce Beetle

One of the most interesting beetles in the spruce forests is the destructive spruce bark-beetle (*Dendroctonus piceaperda* Hopk.). It occurs wherever large white and red spruce are found in the forests east of the Rockies, and closely allied species are abundant in the Engelmann spruce and Sitka spruce of British Columbia. The beetles excavate tunnels between the bark and wood on the trunks of living and dying spruce of all sizes greater than about 6 inches on the stump, selecting particularly the larger trees. Ordinarily they prefer the dying bark of windfalls or fire-killed trees, but during an outbreak they attack and kill the healthiest timber very readily. The Entomological Branch has studied the activities of this species recently in the Gaspé Peninsula and at Frater on the eastern shore of Lake Superior. Some very interesting facts have appeared.

Studies in Gaspé peninsula proved that there were two periods of attack on the tree, one in late June and another in early August. Each female normally cuts two tunnels and lays two batches of eggs, one in June and the second in August, or the first in August and, after hibernating, the second the following June. In Frater, however, the larvae which hibernate less than half-grown mature to adult beetles during the following summer, but do not emerge from the bark until a year later, thus spending nearly two years beneath the bark. The cause of this difference probably lies in the cooler and more humid climate of Frater, but information on this point is still being sought.

It was found that in some valleys the beetles had killed approximately fifty per cent of the large spruce and then had nearly disappeared, leaving the remaining trees uninjured. Much interest attaches to the reason for this possible selection. Did the beetles select those particular trees or was their attack chiefly a matter of chance? It is known that they do select windfalls in preference to trees in any other condition, and overmature and injured trees are undoubtedly selected under ordinary circumstances. In outbreaks, however, such as the cases just cited, a study of the annual rings of beetle-killed trees shows that more than ten per cent of the killed trees were growing as fast as any in the stand, and that a considerable percentage were making average growth. If we could determine that the beetles selected trees with definite characteristics and could thus discover the influence which guided them, we might make practical use of the knowledge in control. It is evident that they are not influenced solely by age and thriftiness of the trees, since trees in varying conditions are attacked and killed.

As the beetles cut the egg-tunnels, gum-tubes form about the entrance holes. When a few beetles attack a healthy tree, it frequently happens that the abundant flow of resin kills the marauders or drowns them out. A study of resin flow was indicated. It was found that the heaviest resin flow came from some of the trees growing very rapidly and also from some growing very slowly. There seemed to be no constant relation between rate of growth and resin flow. From some trees the resin hardens more quickly than from others, and that character would be detrimental to the beetles.

It is known that some influence attracts these beetles to dying trees and to those in a weakened condition, and possibly also to living trees of certain characteristics; but whether it is the resin or the condition of the sap or some other factor is still to be learned. A thorough investigation is needed of cell-sap variations in normal trees, in different seasons, and in weakened and dying trees. It is evident that advance can be made in this study only through the assistance of biochemistry and plant physiology.

The Origin and Decline of Outbreaks

The origin of these beetle outbreaks has been, in the cases we have studied, large bodies of dying bark, usually heavy windfalls. These remain in part green

for two years and often longer, and provide abundant food in which the endemic infestation in the locality may increase to the epidemic stage and spread to the living trees.

The agencies causing the decline of the outbreaks are equally interesting. There are very few parasites, not more than five per cent, in the outbreaks studied, and very few insect predators. Woodpeckers, however, have been shown to be remarkably effective in controlling small outbreaks of this species. They have apparently been largely responsible for the decline of the Frater outbreak.

It appears from these studies that one of the chief factors in reducing the intensity of outbreaks is the tendency of the beetles to overcrowd the brood trees and thereby to ensure that most of the larvae must die of starvation. In the cage studies whole trunks have been caged and all the beetles which emerged from the bark have been captured. Although 100,000 eggs may be laid by the beetles in one large spruce, rarely more than 9,000 beetles can be obtained from the bark. We are now convinced that the chief cause of this larval mortality is overcrowding and resulting starvation. The later-appearing beetles are attracted to the trees already attacked and fill up all the available bark, and, whereas 200 tunnels would kill any spruce tree, a heavily infested tree often has more than 1000 tunnels.

SECONDARY SPECIES

It is interesting that whereas the secondary bark-beetles, *Polygraphus rufipennis* Ky., *Ips perturbatus* Eichh., and *Ips borealis* Sw., apparently entered the tops of trees attacked at the base by *Dendroctonus* in Gaspé, and may have given some assistance in killing some of the trees, at Frater the secondary beetles never entered the top of Dendroctonus trees until the season following the attack.

In connection with these studies it was discovered that the species of *Ips* and some other bark-beetles leave the trees late in the fall during the last warm weather, and hibernate in the moss, a very curious habit for a bark-beetle, and an important one from the standpoint of possible control by slash burning.

The control methods recommended are similar to those employed in the pine bark-beetle outbreaks in British Columbia.

Dendroctonus Beetles in British Columbia

Great outbreaks of Dendroctonus beetles have ravaged the pine forests of western North America for the past 20 years and they illustrate the important part that forest entomology must play in the development of systems of forest management in the areas of western pine.

These outbreaks have been dealt with, hitherto, by direct control measures. In British Columbia, the yellow pine area has been swept by outbreaks of *Dendroctonus brevicomis* Lec., and *Dendroctonus monticolae* Hopk., and the latter species has been equally destructive in lodgepole pine, *Pinus contorta* Loud., and in western white pine, *Pinus monticola* Dougl. *Dendroctonus pseudotsugae Hopk.* has also caused extensive injury in Douglas fir. Control measures have been confined, hitherto, largely to outbreaks of these species and they have, we believe, been remarkably successful.

The method employed has been to cut and burn as nearly as possible all the beetle-infested trees in the outbreak, and to require the burning of all yellow pine logging slash and the utilization of windfalls before the emergence of the Dendroctonus beetles contained in the bark. This work has been carried out under the supervision of the Division of Forest Insects of the Entomological Branch of the Canadian Department of Agriculture in the closest possible co-operation with the Provincial Forest Branch and the Canadian Forest Service, on the lands administered by them, respectively. More than 50,000 beetle-

infested trees have been cut and burned in this control work, at an approximate direct cost of $100,000. It can now be stated that, with the completion of last summer's control work, these destructive outbreaks have apparently been brought under complete control, so that in the future it may reasonably be expected that, provided logging slash is burned, careful annual inspections and an occasional small control operation should suffice to prevent the development of further outbreaks. Judging by all previous experiences with these outbreaks in British Columbia and in similar regions in the Western United States, this control work has saved the commercial yellow pine of British Columbia from almost wholesale destruction.

Outbreaks by *Dendroctonus monticolae* in lodgepole pine have also been dealt with, but, in some cases, with less satisfactory results. In lodgepole pine stands the infestation spreads with such rapidity that, unless the control work is undertaken while the outbreak is very small, there may be little hope for success.

It is reasonable to believe that these destructive outbreaks could be prevented in the future through an efficient system of annual inspections throughout the infested lodgepole pine stands and the prompt application of control work to each small outbreak as it is discovered. With this end in view, it was arranged between the two Branches that special officers of the Division of Forest Insects stationed in British Columbia should visit the ranger stations of the Canadian Forest Service in lodgepole areas of British Columbia and Alberta and instruct the rangers in detecting and reporting lodgepole pine beetle outbreaks and in applying control measures. It is planned to continue this work in 1928 and a similar arrangement has been made with the Provincial Forest Branch. With the admirable system of co-operation that obtains among these three Government organizations, we may confidently look forward to the time when these destructive outbreaks will be prevented throughout the great lodgepole pine areas of British Columbia and Alberta.

Under the conditions that obtain in British Columbia it has been found that large numbers of the destructive beetles breed in the stumps, culled and broken trunks, large tops and neglected logs left from logging operations, and slash burning is considered an absolutely necessary part of these Dendroctonus control operations. The immediate utilization or destruction of wind-thrown and fire-injured timber is equally important.

These direct control methods are necessary at the present time in dealing with bark-beetle outbreaks, and to some extent they will, doubtless, always be employed. It is evident, however, that in a properly managed forest, in which weakened and dying trees are not permitted to accumulate, with efficient fire protection and the rapid disposal of windfalls, infestations of this kind could develop only very rarely. It should be possible, in the future, through forest management based upon the principles of entomology and silviculture, to produce a forest practically immune from bark-beetle attack.

Monochamus Beetles

Several Cerambycid beetles of the genus *Monochamus*, particularly *Monochamus scutellatus* Say and *Monochamus notatus* Drury, attack windfalls, fire-scorched trees and logs of pine, spruce, and balsam fir in Eastern Canada, and are responsible for very extensive losses through their tunnels which are excavated by the larvae deep into the wood. Various methods of control have been employed in the past. Whenever possible, logs which are left in the woods throughout the summer season are secured by booms in lakes or rivers. When it is impossible to place the logs in water they have been protected to a considerable degree by covering the piles with spruce or balsam boughs; but in many cases neither of these methods is possible, as, for example, following an extensive fire when the

timber must be cut as rapidly as possible and no boughs are available for covering the piles. Extensive tests have been conducted for protecting timber from Monochamus beetles under the varying conditions met with in our woods.

Experiments include covering the piles with boughs, earth, and wire netting, in various combinations; and dusting the piles with insecticides, such as lime sulphur, has also been employed in preliminary tests with marked success. Many thousands of white pine logs, left in the Ontario woods on account of the deep snow last winter, are being employed in further experiments this season.

The Larch Sawfly

More than a generation ago a destructive outbreak of the larch or tamarack sawfly, *Lygaeonematus erichsoni* Hartig, swept throughout our eastern forests from the Atlantic Ocean to the Great Lakes and killed the greater part of the tamarack in all that area. It has since spread westward north of the prairies into northern British Columbia and threatens almost complete destruction of the stands of eastern tamarack.

In the eastern forests a new crop of larch is rapidly nearing commercial size, and on this the sawfly is again developing to numbers that threaten its eventual destruction.

Owing to the characteristics of the sawfly outbreak and the low value and scattered nature of the stand of larch, direct control measures are hardly to be considered. Its native parasites are apparently rarely effective in preventing the almost complete destruction of the trees.

Since, however, this insect was probably imported originally from Europe, where it occurs at times in small outbreaks, but is not the destructive pest it has proved to be on this continent, it seemed possible that the introduction of its European parasites, not present in this country, might have very beneficial results. Importations of parasitized larch sawfly cocoons were accordingly made from England to this country by the Entomological Branch in the years 1912 and 1913.

Small colonies were placed at several stations in Eastern Canada and much larger ones at the Spruce Woods National forest and the Riding Mountains National forest in Manitoba, on what was then the western margin of the outbreak.

Very recently it was discovered that the larch in the Spruce Woods forest were recovering their normal health and that the sawfly larvae were no longer abundant. At the same time the European parasite, *Mesoleius tenthredinis* Morley, was found in considerable numbers parasitizing the few sawfly larvae that remained. The imported parasitic species was also recovered last summer in the Riding Mountains Forest. The information available at present permits the hope that a valuable European parasite of the larch sawfly has been successfully established in those two localities at least.

Last season the first shipment of parasitized cocoons was sent from the Spruce Woods forest to the parasite laboratory at Chatham, Ontario, and the parasites which were bred therefrom were subsequently liberated in an infested larch stand at St. Williams, Ont. It is proposed to continue this work and to establish colonies of the parasites at selected stations in different parts of the sawfly infested area, both in the East and in the West. From these stations further distribution can be made, in the hope of establishing this parasite eventually throughout the whole area infested by the larch sawfly in Canada.

The Hemlock Looper

(Ellopia fiscellaria Gn.*)*

Last summer the hemlocks in the country about Muskoka lakes and the upper St. Lawrence were severely defoliated by a caterpillar known as the hem-

lock looper. During the past few years severe outbreaks by this insect have occurred in the states of Wisconsin and Minnesota; and in those outbreaks, very severe defoliation was frequently followed by the death of the trees, and in some sections balsam fir was also severely injured. The defoliation was exceptionally severe in parts of the infested area in Ontario last season and many trees have already been killed; but the injury has been confined entirely to hemlock. These infestations appear rather suddenly, last two or three years, and then disappear for a considerable period. The present attack is more severe than any hitherto recorded from Eastern Canada. Very severe injury to western hemlock has been caused by this species, or one very closely allied, in various parts of the Pacific coast region.

Until recently there has been no practical method of control that could be applied to large areas. The development of airplane dusting, however, has provided a new weapon that may prove of great value. Two years ago an area of 5,000 acres, infested by the hemlock looper, was dusted in Wisconsin with considerable success, using about 20 pounds of calcium arsenate per acre. The Entomological Branch was unable to undertake any experimental work with this problem last summer owing to the pressure of other work already in progress. This season the Ontario Forestry Branch has arranged to conduct an extensive airplane dusting campaign in the Muskoka outbreak, under the direction of the Dominion Entomological Branch, and have obtained a special aeroplane for that purpose. Calcium arsenate will be employed at the rate of between 20 and 30 pounds per acre. An intensive study of all phases of the outbreak is now in progress.

THE HEMLOCK LOOPER IN NEWFOUNDLAND

In Newfoundland this insect is an enemy of balsam fir and, to a lesser degree, of spruce. There is no hemlock on the island. Extensive outbreaks have occurred in which large amounts of balsam have been killed. A few years ago the writer had an opportunity to study the forest insect conditions in parts of the Newfoundland forest, and a very interesting possibility of insect control through forest management appeared to be feasible in connection with the hemlock looper outbreaks.

The forest of the central area of the Island, where the looper outbreaks chiefly occur, is largely a black spruce-balsam mixture, approximately fifty per cent of each, with the balsam grouped into nearly pure stands which thin out into the surrounding black spruce. The ground is everywhere covered with a thick growth of sphagnum moss in which the balsam seeds germinate readily, following a cutting or a looper defoliation which completely opens the crown cover. The spruce seed germinates more slowly under these conditions and is usually almost completely crowded out by the dense stand of balsam seedlings.

On the other hand, following a fire in which the moss and the germinating balsam seedlings are destroyed, the spruce seed germinates readily and a fairly pure stand of spruce results.

The practice in the area referred to is to cut absolutely clean. They are not afflicted by any diameter limit. The looper outbreaks apparently develop only in stands of nearly pure balsam. The limits had been carefully surveyed and it was, therefore, possible to select the areas where balsam predominated.

Lastly, the scarcity of balsam rot in that part of Newfoundland ensures a long period of salvage of dead timber, either that cut in excess of the year's requirement or that killed by the looper. With these conditions, it was possible to devise a plan by which looper outbreaks could probably be eliminated permanently from that whole region.

The following method of control was proposed: To concentrate the cutting largely on the areas containing a high percentage of balsam until these were removed; and to cut clean and burn the cut areas broadcast according to the

method proposed by Gilmour, thus obtaining reproduction containing a high percentage of spruce. The plan was feasible from the standpoint of mill requirements, since the Newfoundland balsam is of good quality for pulp and could be used mixed with only a moderate percentage of spruce. By following this simple plan, within ten or fifteen years a large part of the limits referred to would be almost immune from looper attack. If a looper outbreak developed in the meantime, a plan was proposed for annual scouting for evidence of looper activity and concentrated cutting on the infested areas in the earliest stages of the outbreak.

While it would be more expensive to arrange the cutting in the way proposed, that extra cost would be small compared with the extensive losses that have been caused in the past by looper outbreaks.

There are areas in Eastern Canada which resemble in many ways that part of Newfoundland, and there is apparently still a profitable field for study in the methods of dealing with mixed balsam-spruce stands in order to obtain a higher percentage of spruce in the reproduction.

The Western Cedar Borer

The western cedar borer, *Trachykele blondeli* Mars., is a very destructive enemy of western cedar in British Columbia. The adult beetles deposit their eggs in the bark of the branches and tops of living trees of all sizes. The elongate larvae live for two years and probably longer in the wood and excavate very long tunnels chiefly in the heart wood. When the larva are abundant these tunnels render the wood useless for shingle material and the infested trunks have hitherto been generally discarded for use as poles for telephone and telegraph lines and similar purposes.

Investigations conducted by officers of the Entomological Branch have determined the biology of the insect and established definitely the degree of the injury which it causes. It has been found that its attack is confined to certain regions near the sea level, the injury rarely occurring abundantly at an altitude greater than 700 or 800 feet.

Careful strength tests conducted by the Vancouver Forest Products Laboratory in co-operation with our officers determined that the degree of infestation commonly found in poles did not weaken them at all seriously for commercial purposes, and there is therefore no reason for excluding this material from the market.

A detailed account of the investigation of this insect, now being printed, contains the following summary:

1. The life-history of the western cedar borer has been determined as follows:—Adults emerge from May 10 to June 10. Egg-laying takes place between June 15 and July 15, with an incubation period of from 12 to 18 days. The larval period is at least two years. The pupal stage lasts about 20 days, from late July to early August. The adults remain in the pupal cells from September to May of the following year.

2. A study of the life-history has shown that poles will not become infested after cutting and peeling.

3. Evidence shows that the average length of the western cedar borer gallery is less than 20 feet.

4. The areas in British Columbia which are badly infested by the cedar borer, extend in patches along the mainland coast, the islands of the Inside Passage, and the east coast of Vancouver island, from the International Boundary to Seymour narrows. Heavy infestations occur up the Fraser watershed as far as Harrison lake.

5. It has been found that the most favourable sites for the borers are south-east to south-west exposures, and that there is an altitude limit of approximately 800 feet, above which the borer becomes scarce and the damage negligible.

6. There is no complete method of applied control under present forest conditions, but if cedar slash were burned soon after logging, it would help to prevent the spread of the borer to new areas.

7. The results of submerging a pole in fresh water have not proved successful enough to recommend it as a practical method of killing the larvae of the cedar borer.

8. It has been conclusively shown that there is no material reduction in the strength of a large majority of poles infested by the cedar borer.

9. Evidence collected in the examination of seasoned poles subsequent to testing indicates that the majority of larvae die when the pole becomes thoroughly seasoned, and that the damage caused to poles after cutting is relatively small.

From the strength tests in conjunction with subsequent pole examinations, it is evident that poles which do not show more than four galleries on a single end, or a combined number of more than six galleries on the two ends, are not materially weaker than sound poles, and, other things being equal, would give as good service in a line.

It is hoped that these experiments may help to eliminate some of the present tremendous waste of telegraph poles and effect an appreciable saving to the pole industry by eliminating the loss in handling charges on poles which are later rejected.

Minor Forest Insect Injuries

The European Beech Bark Louse, Cryptococcus fagi Barensp., was introduced many years ago into the province of Nova Scotia, where it has been an important factor in destroying a very large quantity of native beech. The insect has spread more recently into the province of New Brunswick, and a survey of its distribution in that province is now in progress.

This species is proving a most destructive enemy of the beech under the conditions obtaining in the Maritime Provinces. Its habits and the injury it causes have been investigated. While it can be controlled by oil sprays on small areas, no method has yet been devised for dealing with it effectively under forest conditions.

The Bronze Birch Borer, Agrilus anxius Gory, is the most destructive enemy of the white birch in the forests of Eastern Canada. It probably affects all species of birch in that area and is equally common though less injurious in native poplars.

The larvae bore in the sapwood and girdle the limbs and trunk, working from the top of the tree downward.

Under the present forest conditions no method of control is feasible.

The Maple Leaf Cutter, Paraclemensia acerifoliella Fitch, has occurred periodically in injurious abundance in the sugar maple groves of Quebec and Ontario. An infestation near Ottawa is being utilized in an intensive study of environmental factors.

The Forest Tent Caterpillars (Malacosoma) occur periodically in intensive outbreaks affecting poplars in both eastern and western Canada. During the last few years they have been particularly injurious in Saskatchewan and Alberta and are the subject of special investigations.

The White Pine Weevil, Pissodes strobi, is the most important insect enemy of eastern white pine in Canada. The weevils lay their eggs in the terminals of young trees from five to thirty feet or so in height, and in severe infestations

the trees are severely checked in height growth and ruined for commercial purposes. Under suitable conditions of mixture with other trees, the weevil injury is not so severe, and planting experiments are now in progress on cut over and burned areas and with pine and poplar mixtures, in the hope of determining the shade conditions which will give immunity from weevil injury.

The Spruce Gall Aphides. Various species of the genus *Adelges* (*Chermes*) are important enemies of spruce shade trees, though of little general importance under forest conditions. Detailed studies of the biology and control of these insects have been conducted in Eastern Canada and in British Columbia.

BIOLOGY OF CANADIAN BARK-BEETLES

During the course of an investigation carried out some years ago in the Gaspé peninsula, of Quebec, it was discovered that adults of *Dendroctonus piceaperda* Hopk., *Polygraphus rufipennis* Kby., *Ips perturbatus* Eichh., and *Ips borealis* Sw. cut two sets of tunnels the same season and in some cases hibernated and cut tunnels in the following season. Subsequently, a series of detailed studies on the biology of Canadian bark-beetles has been in progress in field laboratories at Fredericton, N.B., Frater, Ont., Vernon, B.C., and Pender Harbour, B.C.

It has been found that many of our northern species of bark-beetles cut more than one set of tunnels in the same season and that what had previously been considered as a series of generations are in reality, in these cases, a series of broods originated by the same parent adults. Certain species have cut one, two, or three sets of tunnels in different seasons in the same locality, and others have required two years for the completion of their life-history at Frater, Ont., whereas the progeny of the same beetles have developed from egg to adult in one year when transferred to the more southerly latitude of Fredericton, N.B. These differences are probably to be explained in part by climatic variations and in part by other conditions, such as the amount of bark available for their use.

In these studies the infested logs are kept in cages, four or eight feet in length, covered with fine wire or thin cotton cloth or both; fresh logs are supplied in time to accommodate the old parent adults or the young beetles when they emerge to cut new tunnels, and the newly infested logs are then transferred to separate cages.

Larger cages are employed to enclose the entire infested part of the trunk of special trees and others are constructed about portions of the trunk of living standing trees.

METHODS OF FOREST INSECT CONTROL

It is evident that entomologists have two viewpoints in considering the subject of forest insect control.

On the one hand an attempt must be made to provide for permanent control of insect conditions through systems of forest management that will render the forest immune from insect attack. That condition probably can be attained with respect to many destructive species, including the primary bark-beetles, the spruce budworm, and the hemlock looper on balsam fir in Newfoundland. It is probable that the measures already recommended will be carried out successfully as soon as large areas of our forest are brought under definite systems of management. In dealing with each forest insect problem an effort should be made to discover the conditions, applicable in our forests, which will provide permanent immunity.

The other viewpoint, however, must not be overlooked. At the present time our forest is very far from being immune to insect injuries. In order to save as much timber as possible from insect attack, we must endeavour to provide direct means of control, such as those employed now so successfully for bark-beetle outbreaks and airplane dusting with which we are now experimenting.

Preventive measures and control measures for forest insects must depend upon the nature of the attack, the habits of insects, the reaction of the trees to the injury and upon the local conditions respecting management of the forest.

In dealing with defoliating insects such as the spruce budworm, the hemlock looper and the larch sawfly, there is as yet no proven and satisfactory direct method of control. It seems possible that outbreaks of the budworm and the hemlock looper may in the future be held in check, at least on limited areas of valuable timber, through the distribution of poison dusts from air machines. Airplane dusting operations carried out in several European forests last summer gave promising results, and our own experiments lead us to be hopeful. If this method can be developed so as to be applicable to large forest areas, it will revolutionize the present methods of dealing with forest defoliators.

In Europe, attempts have also been made to control defoliating insects by poisonous fumes liberated by burning candles composed of an arsenic compound, with a view to obtaining a sufficiently heavy deposit of arsenic on the foliage to kill the feeding insects. It is reported that considerable success was achieved in Poland with this method last season, and further investigation may be expected in the future.

The importation and distribution of parasites and the protection of insectivorous birds are promising methods for development and their value should be strongly emphasized.

The injury caused by some of the defoliators depends largely upon the thrift and general condition of the stand, and there is considerable assurance that in a forest under proper management these outbreaks would develop less rapidly and would prove much less destructive. Recent studies of the spruce budworm conducted in Eastern Canada have supported this view, and similar exhaustive studies of the relations between the insect attack and the development of the timber are essential for further progress with any injurious species.

Various special methods for prevention or control are practised in connection with particular problems, such, for example, as varying the season of cutting operations to avoid insect attack or banding the trunks of trees to prevent the ascent of climbing caterpillars or egg-laying moths. Some of these methods, which are feasible under the labour conditions and intensive forestry systems of Europe, are impractical in Canadian forests, owing chiefly to the excessive cost of the operation. For example, the remarkable success obtained in the Saxon forests a few years ago in controlling the nun moth outbreak by banding the tree trunks with tree tanglefoot would be impossible under the present conditions of expense and ground cover now obtaining in any part of the Canadian forests.

In the study of all these forest insect problems, especial attention is being devoted to the natural conditions which influence the development and control of great periodic insect epidemics. The present spruce budworm and hemlock looper outbreaks in Ontario are being utilized for this purpose, and it is planned to study these problems intensively throughout the complete cycle of infestation. The effect of such factors as temperature and humidity of soil and atmosphere, sunlight, air circulation, soil fertility, ground cover, and the like, presented under the different conditions of latitude, altitude and forest mixtures obtaining in Canadian forests require much further investigation.

Some of these difficulties will eventually be solved through systems of forest management; but it is evident that, owing to the vast extent of the forested area of our country, many years must elapse before forest management can have more than a local effect in preventing great outbreaks of defoliating insects. Two lines of effort are indicated. Investigators in entomology, mycology and silviculture must co-operate in the study of these problems, so that the results of their investigations can be incorporated into plans for forest management; and, in the meantime, we must utilize every feasible method of direct control that becomes available.

OUTLINE OF INVESTIGATIONS ON FOREST AND SHADE TREE INSECTS CONDUCTED IN 1927 IN THE CANADIAN ENTOMOLOGICAL BRANCH

Spruce Budworm Investigations—Investigations continued in Ontario, Cape Breton, Manitoba and British Columbia. The effects of the infestations, parasitism, and disease affecting the insect and of direct control measures through forest management and airplane dusting.

Insects Injurious to Fire-killed Timber, Windfalls and Logs—A study of the injury and of special methods aiding control (Central Ontario, Western Quebec and New Brunswick).

Eastern Spruce Beetle.—Observations continued at Frater, Ont., and Cape Breton island. Effects of infestation in different forest types.

Douglas Fir Bark-beetle—Surveys of areas previously inspected and of several new infestations reported in 1927, from different parts of British Columbia.

Satin Moth—Determination of the limits of the infestation and control work in the parks, Agassiz, B.C.

Lecanium Scale—Surveys and control by spraying in Stanley Park, Vancouver, B.C.

Pine Bark-beetles—Field studies and cage experiments on the biology of the beetles affecting pine, Vernon, B.C.

Bark-beetle Control Operations in British Columbia—In co-operation with the Provincial and Dominion Forest Services. Cutting operations under the direction of Entomological Branch officers continued from Vernon, B.C.

Biologic Studies of Eastern Bark-beetles—Life-history studies and observations on the habits of the most important species found in Eastern Canada; Fredericton, N.B., Frater, Ont.

Balsam Weevil—Studies in the biology and habits of the balsam weevil with special reference to methods of attack and spread of the infestation; Fredericton, N.B.

White Pine Weevil—Studies of the effect of mixed planting on the liability to attack of white pine by this insect. Mixed stands were studied stemwise and groupwise and the amount of damage regulated for different forest types; New Brunswick and Nova Scotia.

Larch sawfly—Study of the damage due to the larch sawfly in the sample plots established at Fredericton, N.B., and in similar plots west of North Bay, Ont.

Larch Sawfly Parasites—Survey of the larch stands in Manitoba, Ontario and Quebec, where the imported parasites were released fifteen years ago. Effects of parasitism noted. Release of the parasites in all important larch stands.

Biologic Studies of Forest and Shade-tree Insects—Numerous insects were studied at Fredericton, N.B., Aylmer, Que., Frater, Ont., Indian Head, Sask., Vernon, B.C., and Ottawa, Ont.

Insects Affecting Maple Trees—Field observations and laboratory experiments to determine various factors in the life-history of insects affecting sugar maple, more especially the maple leaf cutter and the maple borer; Ottawa, Ont.

Study and Control of Shade-tree Insects in the Prairie Provinces—Extensive studies of the forest tent caterpillar; its natural and artificial control in plantations and forests. Studies of mites and leaf-scale on evergreens and control operations on these trees. Special investigation of the bronze birch borer in a recent outbreak at Indian Head, Sask.; Indian Head, Sask.

European Beech Bark Louse—Surveys to determine the spread of the insect and studies in control conducted from Fredericton, N.B., and Nova Scotia.

Spruce Chermes—Notes on the biology and habits of the insects and experiments in control; Fredericton, N.B.

Western Cedar Borer—Strength tests on wormy poles conducted in co-operation with the Dominion Forest Service at the Forest Products Laboratory, Vancouver, B.C., and a continued study of the biology.

Hemlock Looper—Survey and general information gathered through correspondence on the present status of the hemlock looper in Ontario, with a view to further studies during 1928.

Classification, Biology, and Control of Bark-beetles in British Columbia.

Classification, Biology, and Control of Bark-beetles in Canada.

Classification, Biology, and Control of Cerambycidae, Buprestidae and other forest Coleoptera of Canada.

Classification, Biology, and Control of Scale Insects of Canada.

Classification, Biology; and Control of Forest Lepidoptera.

Classification of Lepidopterous Larvae.

Classification of the Genus Ips in North America.

Classification of North American Lepturini.